THEORETICAL SIMULATION OF SOLAR SPECTRA IN THE MIDDLE ULTRAVIOLET AND VISIBLE FOR ATMOSPHERIC TRACE CONSTITUENT MEASUREMENTS

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Submitted by

A. Goldman

Department of Physics

University of Denver

Denver, Colorado 80208

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In previous work under this project[1,2] the stratospheric NO_2 mixing ratio profile was derived from the data obtained during the 9 February 1977 balloon flight. This work has been extended to the 17 February 1977 balloon flight, from which another NO_2 profile was derived. Typical high sun and low sun scans and their ratios already corrected for Rayleigh scattering are shown in Figure 1, along with synthetic spectra of O_3 and NO_2. The spectral absorption coefficients used for NO_2 and O_3 have been tabulated previously[1]. Figure 2 shows the NO_2 amounts at three peak absorption wavelengths as determined from several pairs of high sun and low sun spectra. The NO_2 amounts obtained from the two flights are compared in Figure 3 with an earlier NO_2 profile obtained from infrared solar spectra obtained during sunset.[3] Only minor changes can be observed among these three winter profiles.

The data obtained during the 9 February 1977 flight (float altitude ~40 km) have also been studied for possible ClO identification. Figure 4 shows high sun and low sun spectra with a simulation of O_3 and ClO absorptions in the 2950-3100A region which are based on the known O_3 absorption coefficients and on recently calculated ClO cross-sections.[4] The O_3 amount is based on a ray-tracing calculation with a standard O_3 profile;[1] the ClO amount was selected to show a ~10% absorption near 3035A. The ClO absorption increases toward the short wavelength end of Figure 4 and peaks near 2800A. Unfortunately, because the increasing O_3 absorption toward the short wavelength end dominates the spectrum in this region, ClO cannot be identified in these spectra. A similar study is being conducted for the 17 February 1977 flight.

The data compiled during the present study also allow a detailed examination of the attenuation of the solar radiance by the combined effect of the atmospheric trace gases and the SAGE filters. The case of the 0.447μm channel is presented in Figure 5. The amounts of NO_2, O_3 and the airmass were chosen to closely simulate a low sun spectral scan from the 9 February 1977 balloon flight.[1,2] The solar radiance outside the earth's atmosphere was determined from the AFGL Sacramento Peak Observatory (SPO)[5] spectral data tape degraded to 2.0A resolution and normalized to Thekaekara's absolute intensities (as described in Ref. 5). The spectral absorption coefficients used for NO_2 and O_3 have been tabulated previously.[1]

From these calculations, effective extinction coefficients (weighted by filter response function) can be established which will allow Beer's law (also weighted by the filter response function) to be applied to the analysis of data collected with the 0.447μm channel. The coefficients are 3.98×10^{-3} ($atm^{-1}cm^{-1}$) and 12.3 ($atm^{-1}cm^{-1}$) for O_3 and NO_2 respectively, and 0.229 ($airmass^{-1}$) for Rayleigh scattering. These calculations will be redone once the final data on this channel become available. The SPO tape provides solar spectral data between 0.38 and 0.7μm, so that these computations can be readily performed for the 0.6μm channel. The SPO data, though, does not cover the full range of the 0.385μm channel or any part of the 1.0μm channel. High sun scans from the 9 February 1977 balloon flight can be used to provide the solar spectral data for the 0.385μm channel. If calculations of this type are required at 1.0μm, an additional source of solar spectral data must be found.

Absorption coefficients have been compiled from the literature[6,7] for NO_3 in the 4000-7000A region, as shown in Fig. 6. An absorption spectrum has been calculated for 0.001 cm-atm NO_3 as shown in Fig. 7. The NO_3 amount was chosen to produce ~10% absorption near the 6000A peaks. The wavelength region of the stronger peaks were not covered during the February 1977 flights. Comparisons with the flight data showed no observable features due to NO_3. Since the wavelength of the strongest peak (near 6700A) was not covered, and since previous observation showed atmospheric NO_3 during nighttime[8], it is not surprising that NO_3 was not observed on the current data.

Absorption coefficients have also been compiled for HNO_2[6], in the 3000-4000A region, as shown in Fig. 8. An absorption spectrum of 0.035 cm-atm HNO_2 is shown in Fig. 9, chosen to produce ~10% absorption near 3700A. No observable features due to HNO_2 could be identified on the Feb. 1977 flights data.

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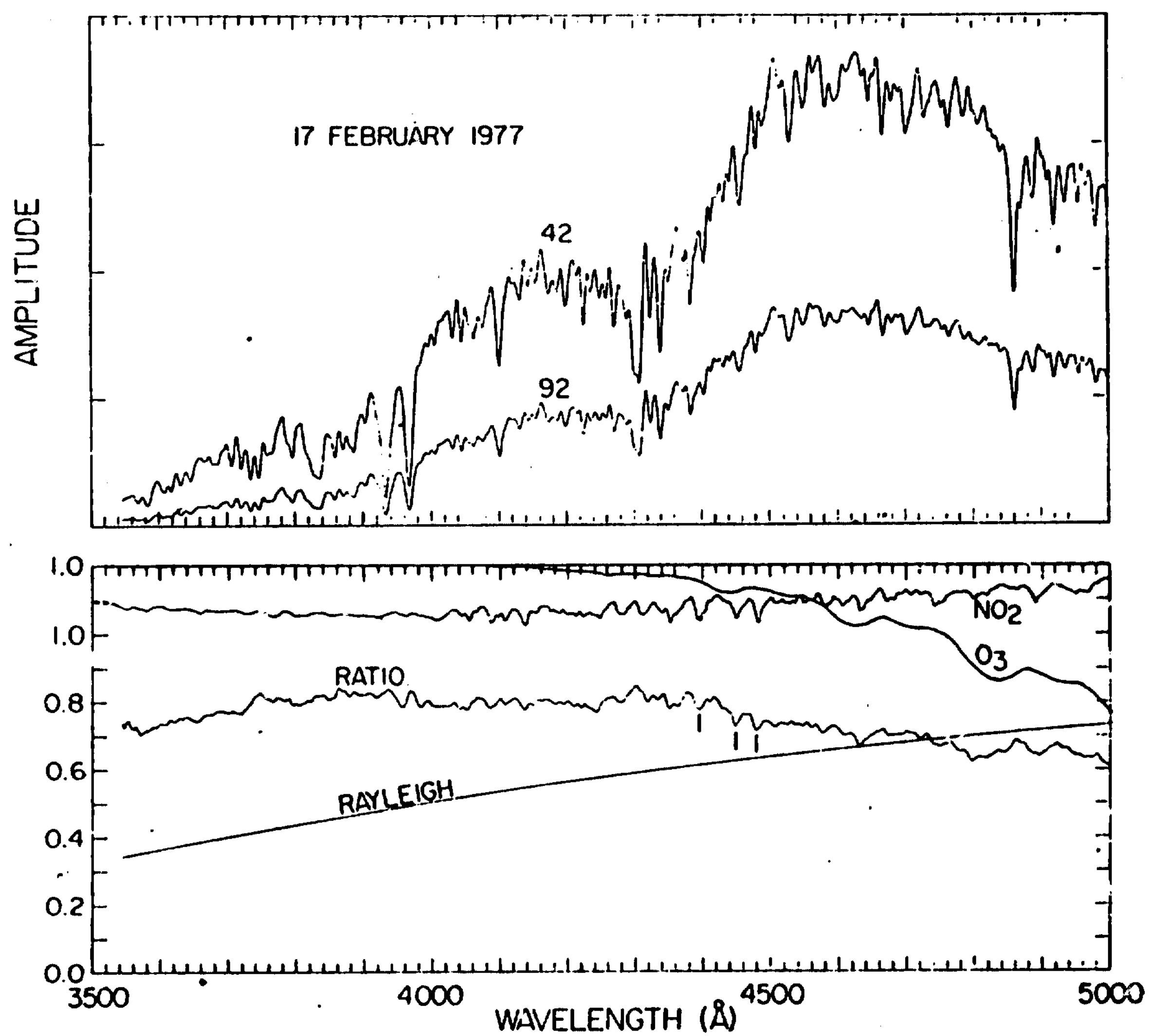

Figure 1. Top Frame: Scans 92 and 42, degraded to ~5A resolution. Bottom Frame: ratio of degraded scans 92 to 42, corrected for Rayleigh scattering and synthetic spectra of NO_2 (0.01 atm cm) and O_3 (20 atm cm). The vertical axis for NO_2 and O_3 is transmittance (0 to 1 scale) and is shifted upwards two divisions from the 0 to 1 scale for Rayleigh corrected ratio.

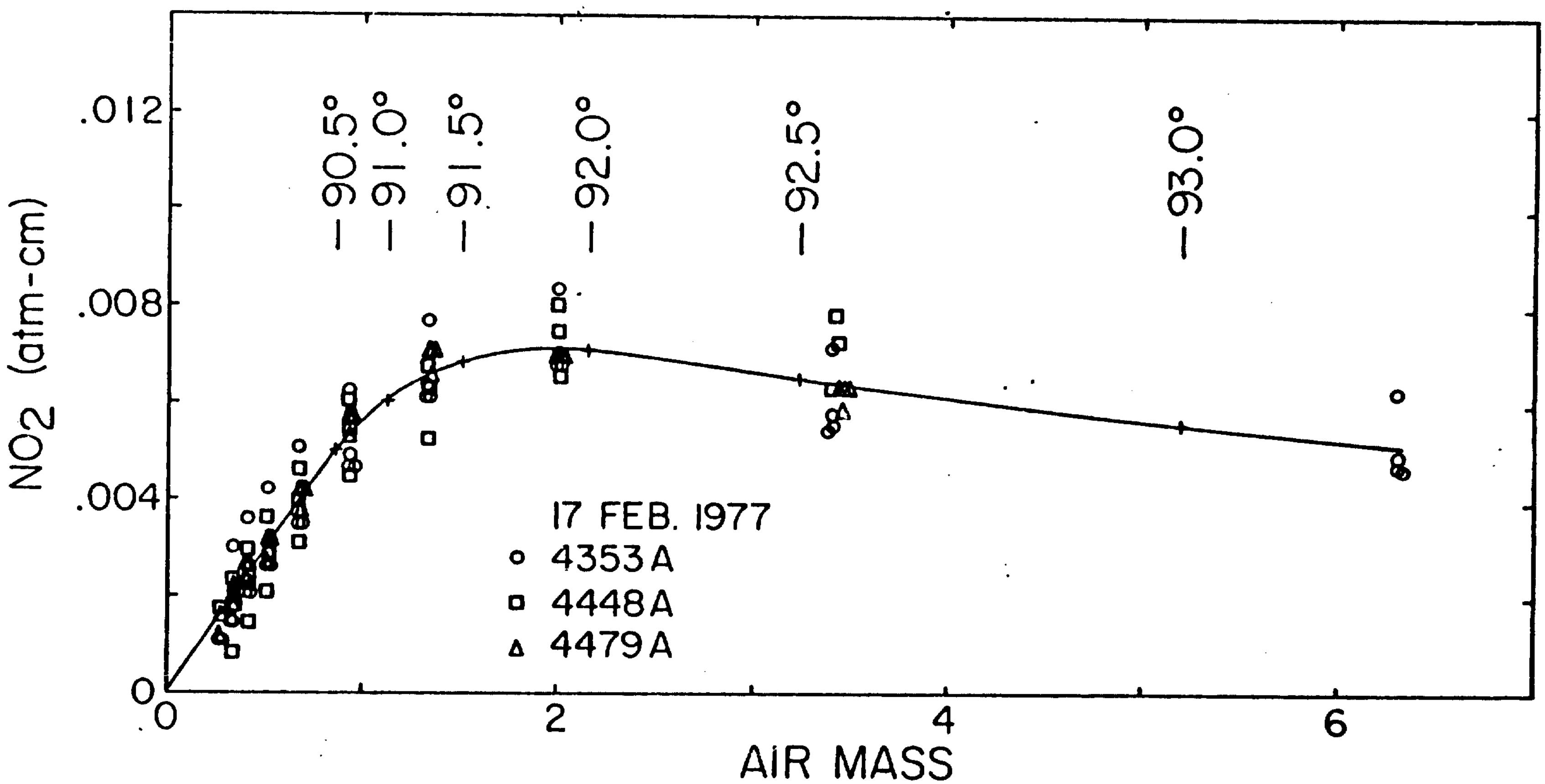

Figure 2. NO_2 amounts and apparent zenith angle as derived from several sunset paths during the 17 February 1977 flight from float altitude of ~30 km. For each of the NO_2 absorption peaks at 4393, 4448 and 4479A, several pairs of high and low sun scans were used. The airmass is calculated at the time corresponding to NO_2 absorption within each scan.

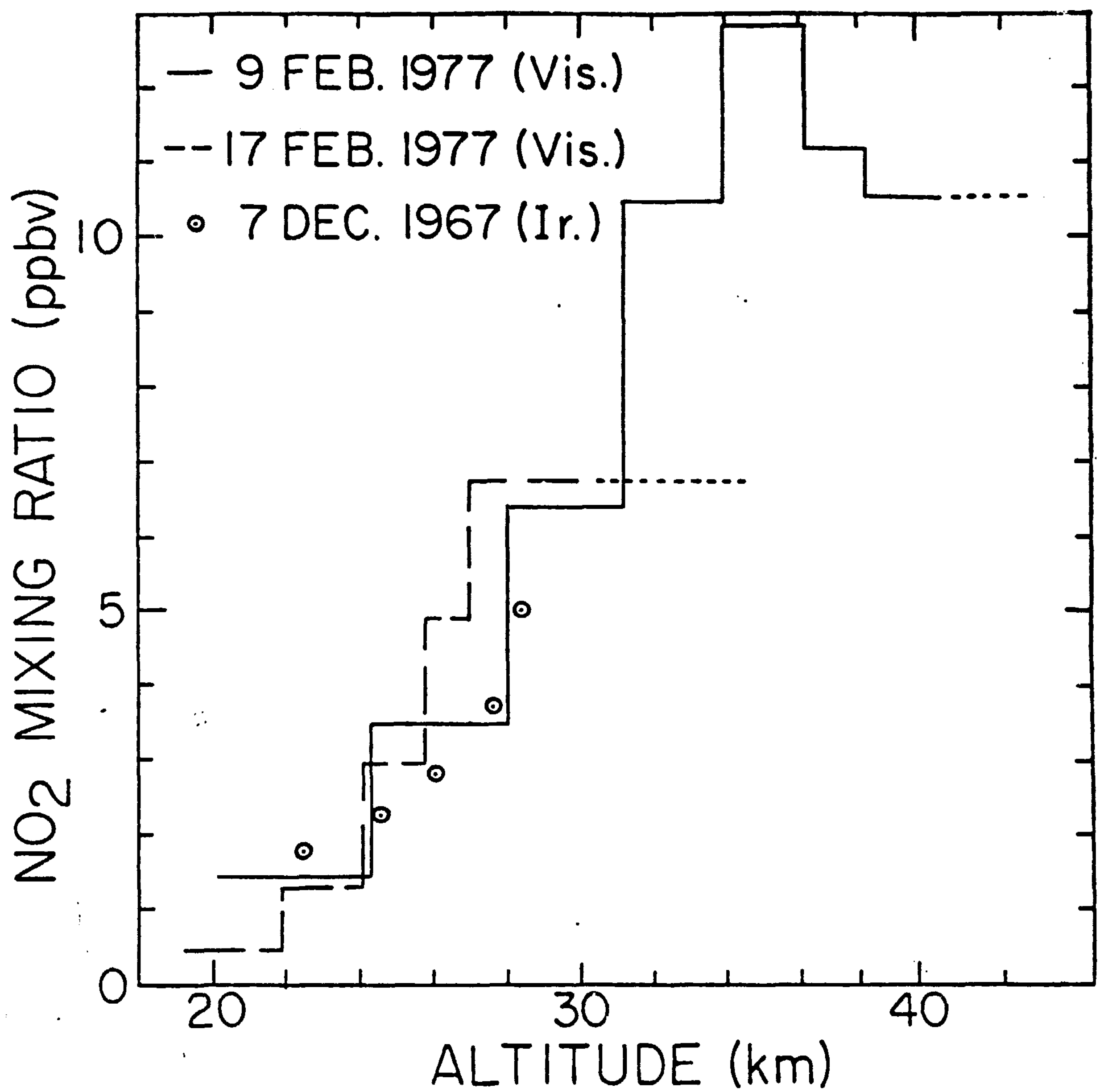

Figure 3. Mixing ratios of NO_2 as derived from three balloon flights from Holloman Air Force Base, New Mexico.

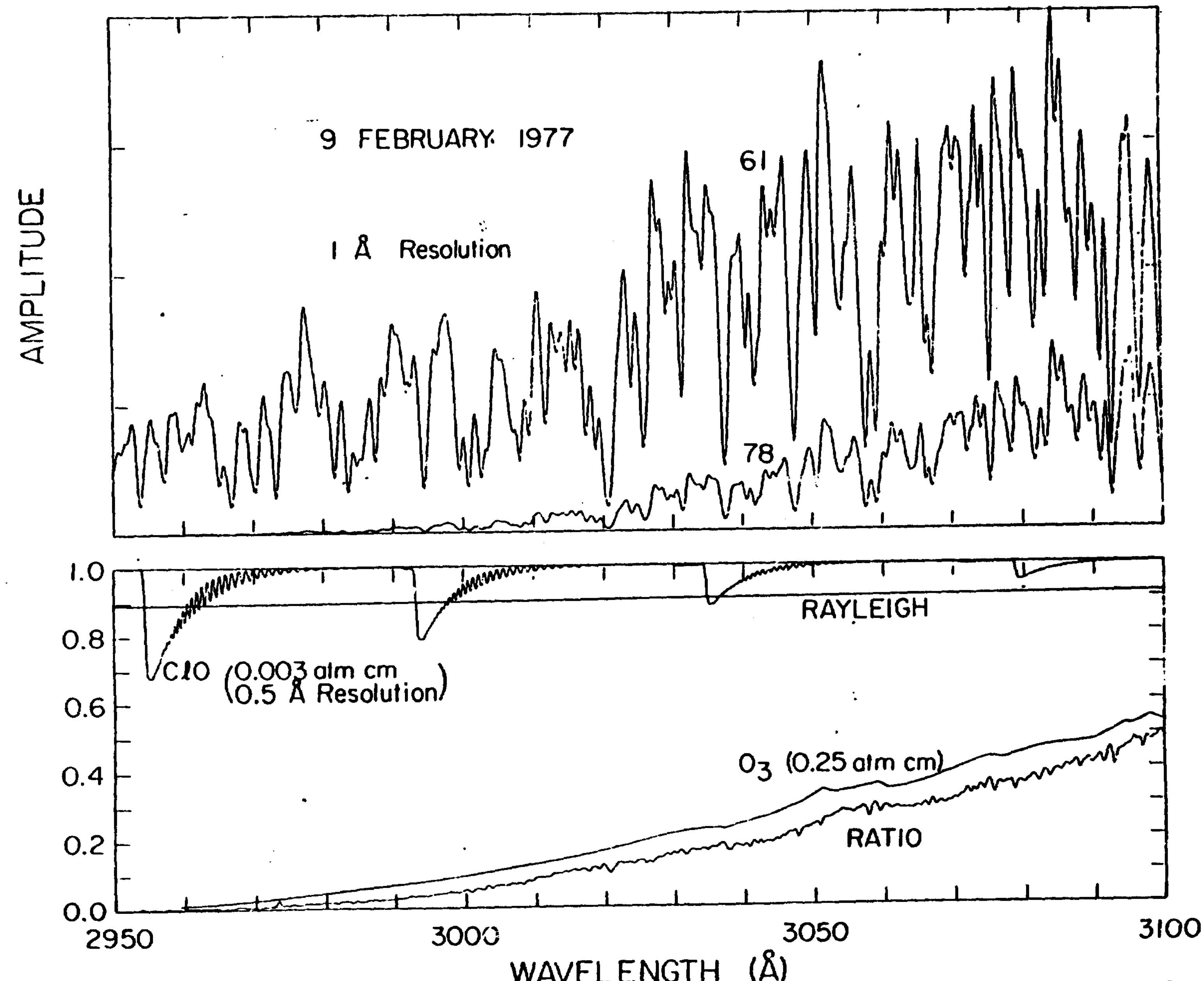

Figure 4. Top Frame: amplitude vs wavelength for scans 61 (solar zenith angle of 78.89°) and 78 (solar zenith angle of 89.02°) from the 9 February 1977 flight degraded to ~1A resolution. Bottom Frame: ratio of the degraded scans 78 to 61, corrected for Rayleigh scattering, and synthetic spectrum of 0.25 atm cm O_3 at ~5A resolution and 0.003 atm cm ClO at 0.5A resolution. The vertical axis is a 0 to 1 transmittance scale.

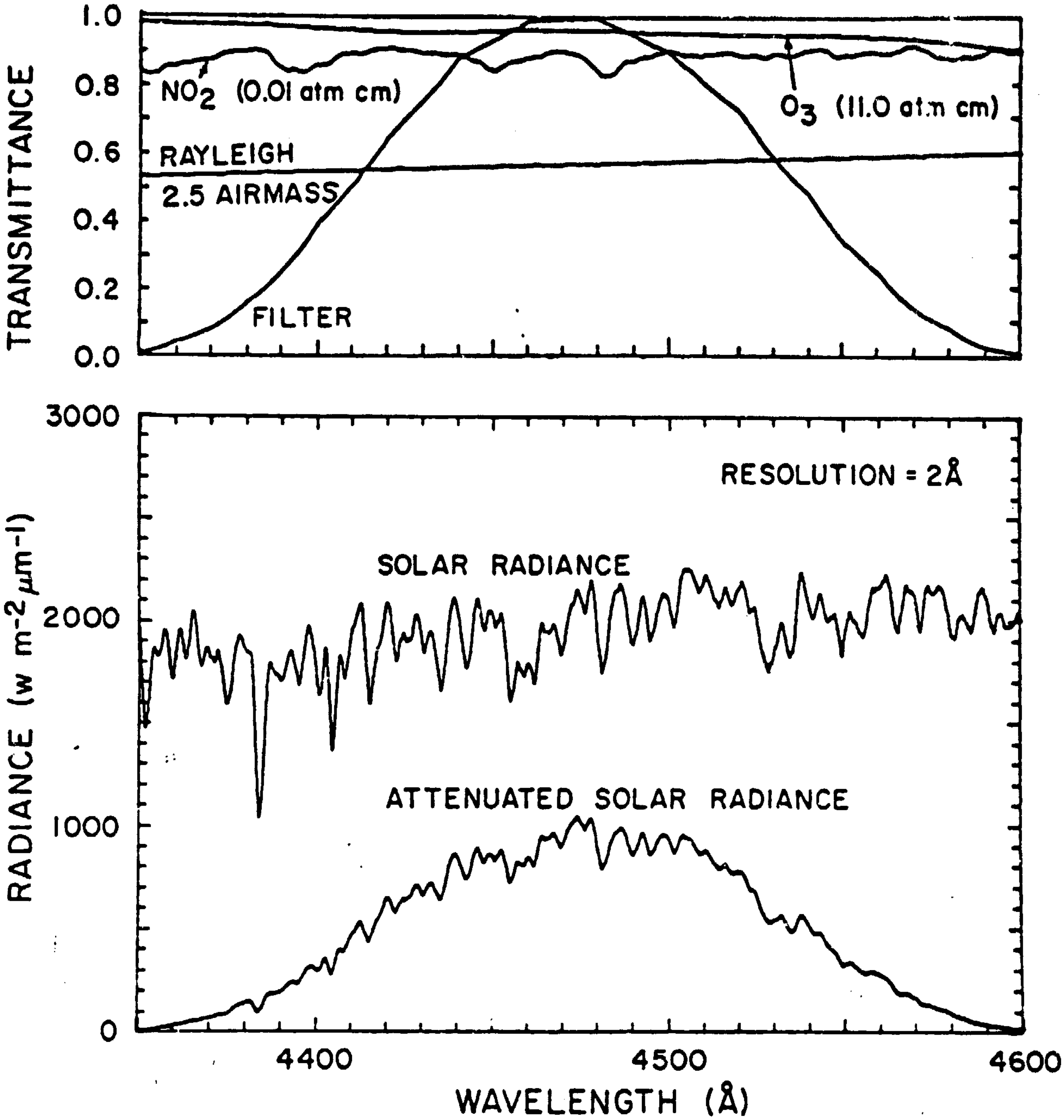

Figure 5. Simulation of the attenuation of the solar spectrum in the 0.447μm channel of the SAGE experiment. Top Frame: the normalized filter detector response, the Rayleigh scattering atmospheric transmittance, the NO_2 and O_3 transmittance over the filter bandpass. Bottom Frame: the solar radiance outside the earth's atmosphere as modified by all the transmission losses shown in the top frame.

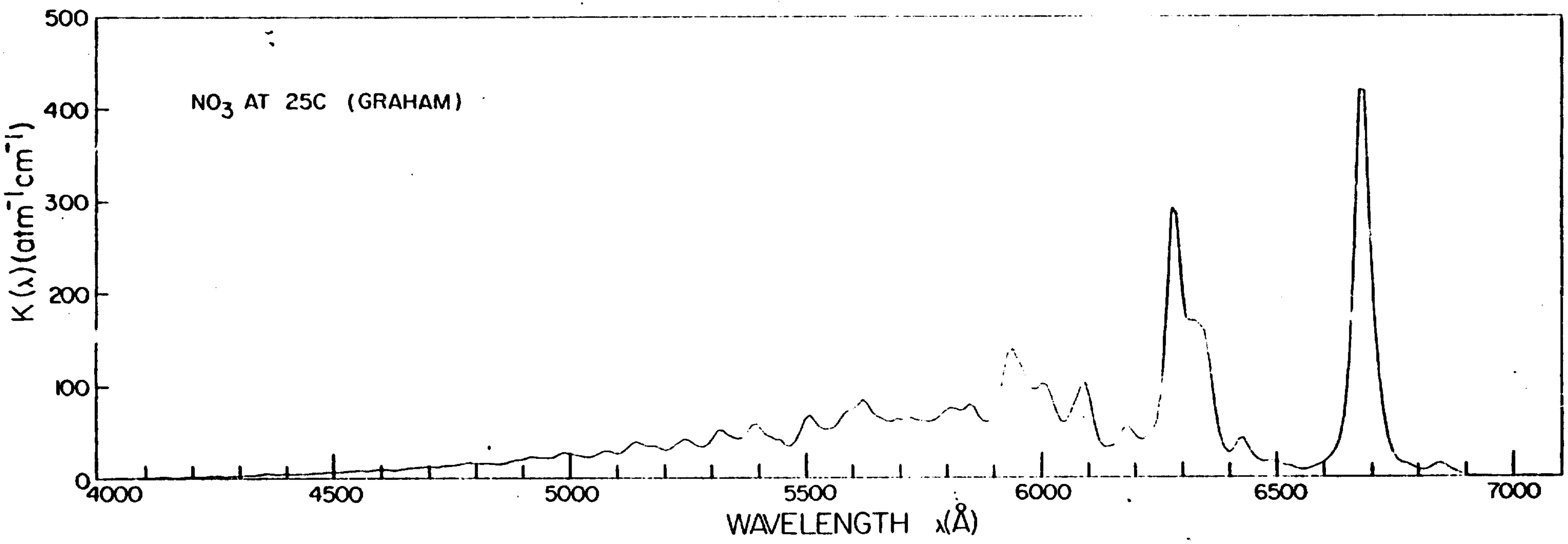

Figure 6. Absorption coefficients of NO_3

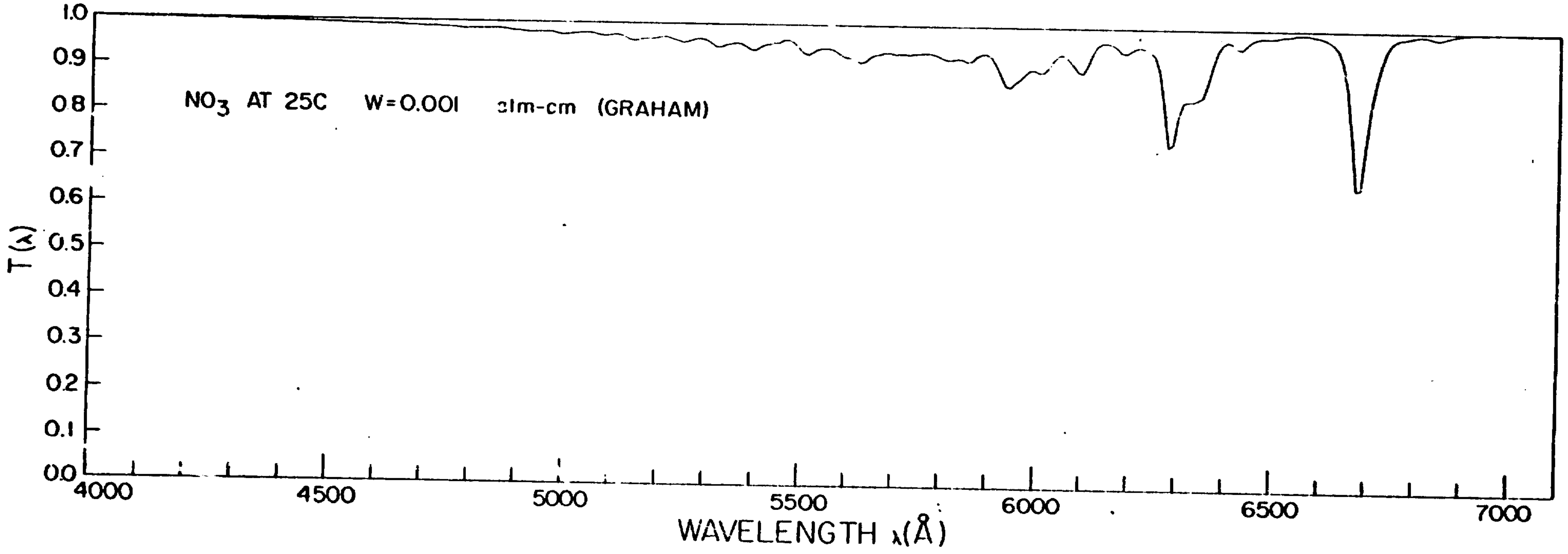

Figure 7. Transmittance of NO_3

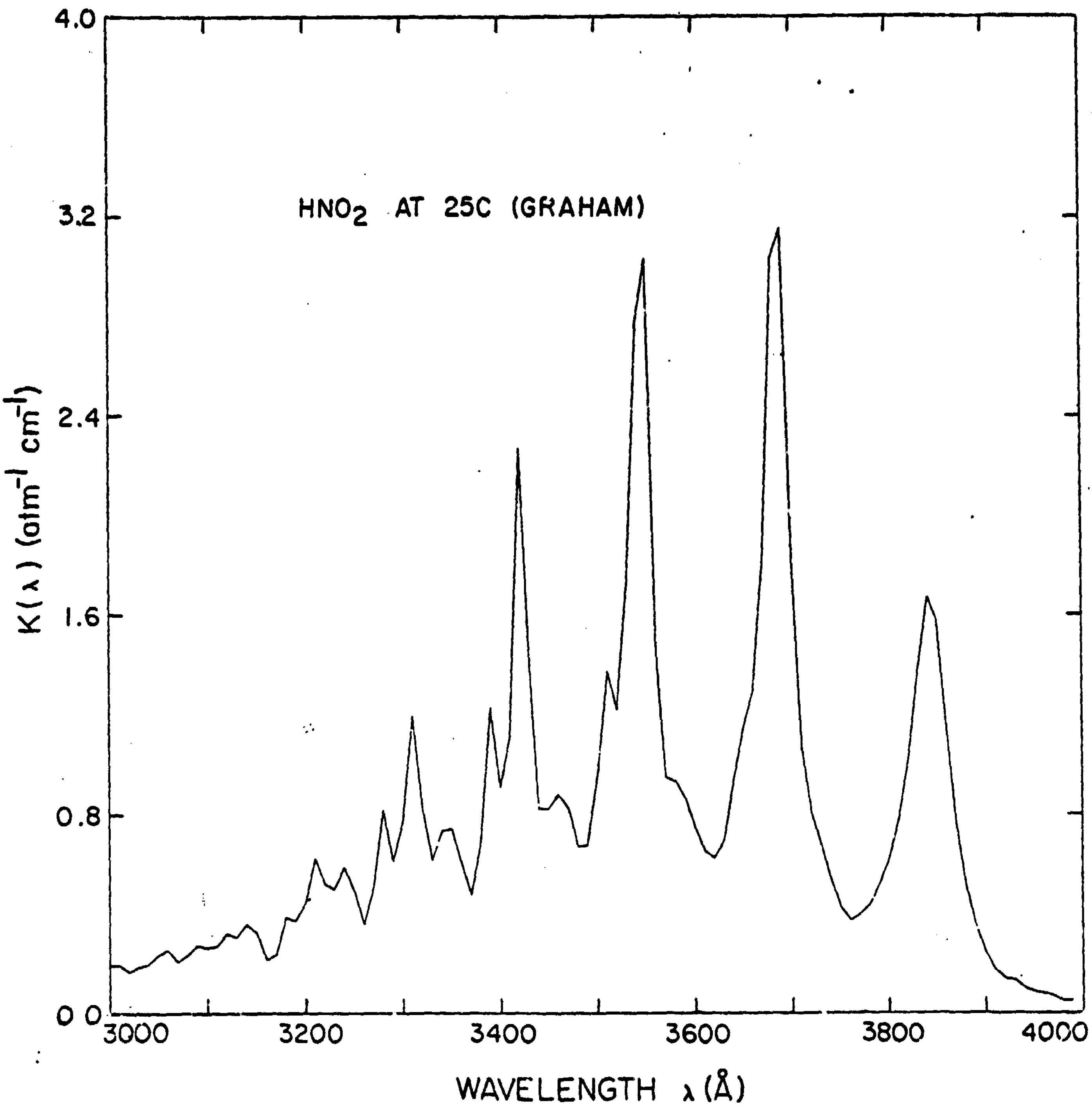

Figure 8. Absorption coefficients of HNO_2

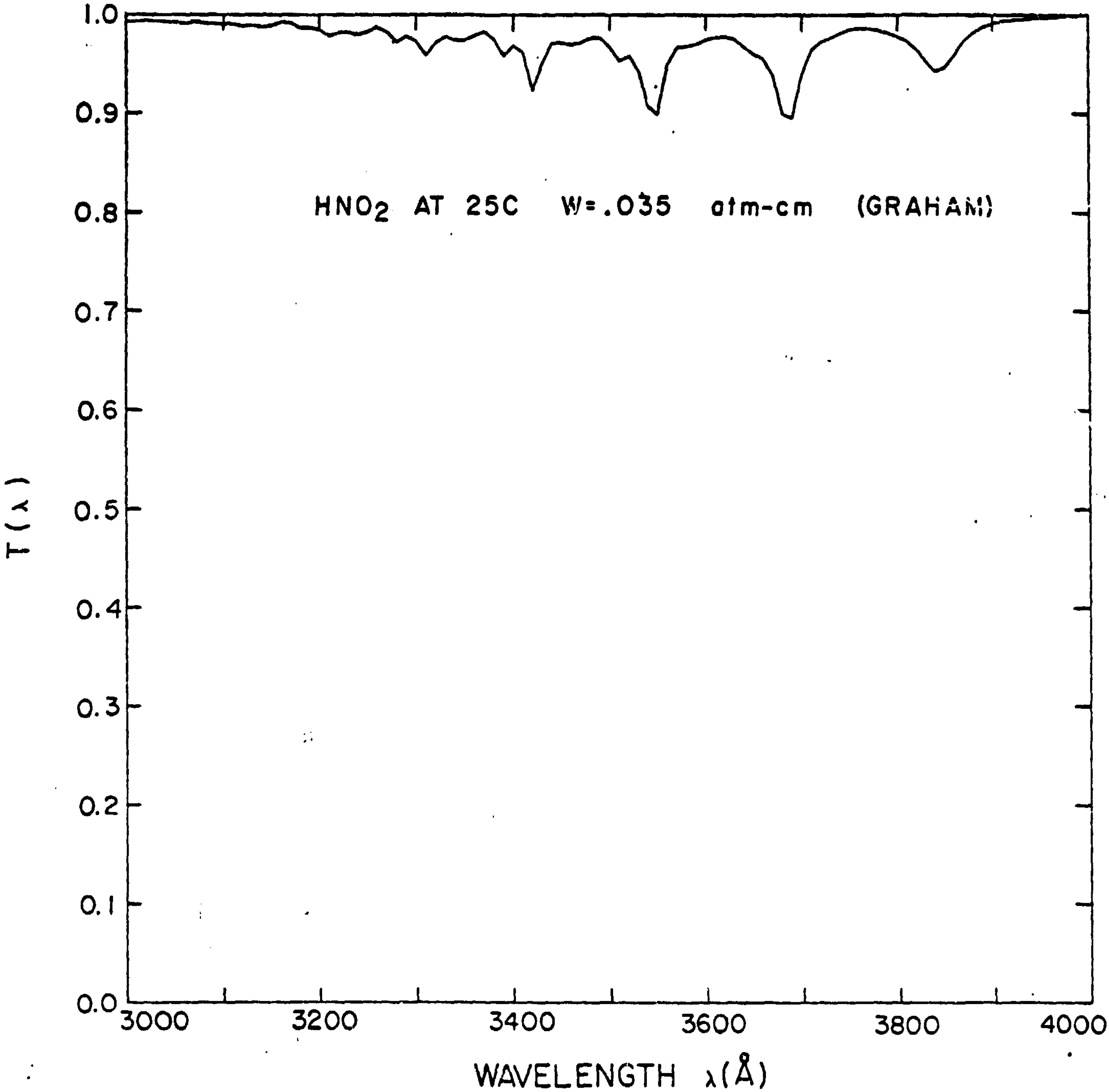

Figure 9. Transmittance of HNO_2